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Study On The Kinematics Of Windshield Wiper Mechanisms Of A Car By Using An Engineering Software.

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Abstract. The objective of the article is to make a synthesis of kinematic models of wipers with one and two blades operating on the windshield of a car. With selected windscreen sizes of 1.5x1.3x0.8m with an area of 1.12m^2 and selected blade sizes 0.4; 0.5; 0.55; 0.6; 0.65; 0.7m, the area covered reaches up to 63%. In the common types of assembly the blade operation angle reaches up to 88°. Diagrams of the analyzed mechanisms of work of the common two blades are shown and dependencies about the operation angles of the blades have been derived. Percentage relations of covered area depending on the assembly of one- and two-blade mechanisms have been presented in a table format.

INTRODUCTION

The windshield wiper is a very important component of the vehicle used to remove rain, dust and other debris. It makes driving in rain possible and reduces danger. In most countries of the world there are regulations of legal requirements that make it mandatory for every car to be equipped with windshield wipers. The mechanism of a wiper consists of an arm, a blade filler, a lever mechanism including rods and ball joints, an electric motor, a worm gear mechanism [2] [7] [10] [11]. Most cars have two windshield wipers, one rear wiper and one on each headlight. Each time water makes contact with a special sensor located on the windshield, the sensor will send a signal to the motor that drives the wipers. The wipers will continue to operate as long as there is water or other debris making contact with the sensor. This will prevent the temporary blindness of the driver and reduce the prerequisites of a road transport accident caused by the loss of visibility to the environment and the road [2] [5]. With the conventional wiper system, when it starts raining, the driver must engage the wiper lever. Rain intensity sensing should be provided for automatic wiper operation [4]. There are various assembly mechanisms for wiper operation, the most widely applicable being those with two arms. To provide a good contact area with the windshield, the length of the blade fillers varies from 260 to 1000 mm. The coefficient of dry friction in the contact zone of the glass has been found to be between 0.8 and 2.5. In wet friction it varies between 0.6 and 0.1. In the area of contact, the edge of the blade filler must form an angle of 45° when sliding on the windshield, which will guarantee correct and precise operation of the wiper [6].

MATERIAL AND METHODS

In order to make a synthesis of the kinematic models of wiper mechanisms, the SAM (Synthesis and Analysis of Mechanisms) software package is used [8]. SAM is used to design, analyze and optimize mechanisms employing a computer. In order to study and evaluate the performance of the individual mechanisms, the areas covered by the wiper blades on the windshield are calculated. The glass surfaces are divided into four as shown in Figure 1:

- Area 0 – the area of the glass not covered by a blade filler or fillers, m^2.
- Area 1 – the area of the glass covered by the first blade filler. This area can vary depending on the assembly and synthesis of the mechanism, as well as the length of the blade filler, m^2;
- Area 2 – the area of the glass not covered by the second blade filler. This area can vary depending on the assembly and synthesis of the mechanism, as well as the length of the blade filler, m^2;

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- Area 3 – area of the glass covered simultaneously and consecutively by the two blade fillers, m^2. This area is the partial area covered by the consecutive operation of the blade fillers in tandem;
- Area 4 – the total glass area, m^2.
- Area 5 – the total glass area covered by a single blade or a tandem blade operation, m^2. This area is the entire area covered by a single blade or a tandem blade operation.

The modes of blade operation depending on the assembly of the mechanism are:
- a system for tandem operation;
- an opposing system;
- a single blade system;
- complex and eccentric arc systems.

A description of the mechanism of wipers for tandem operation is shown on Figure 2 [3]. The movement of the mechanism is provided by an electric motor 1 and a gearbox 7, which transmits torque to the crank 9. The crank is attached to the shaft of the gearbox with a nut and transmits the movement to the mechanism through a connecting rod or conrod. The motor with the gearbox are mounted on console 3, and the entire set of the mechanism is mounted through housings 10 and 11 to the car body.

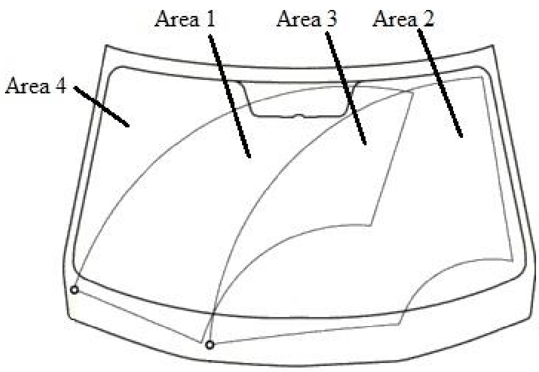
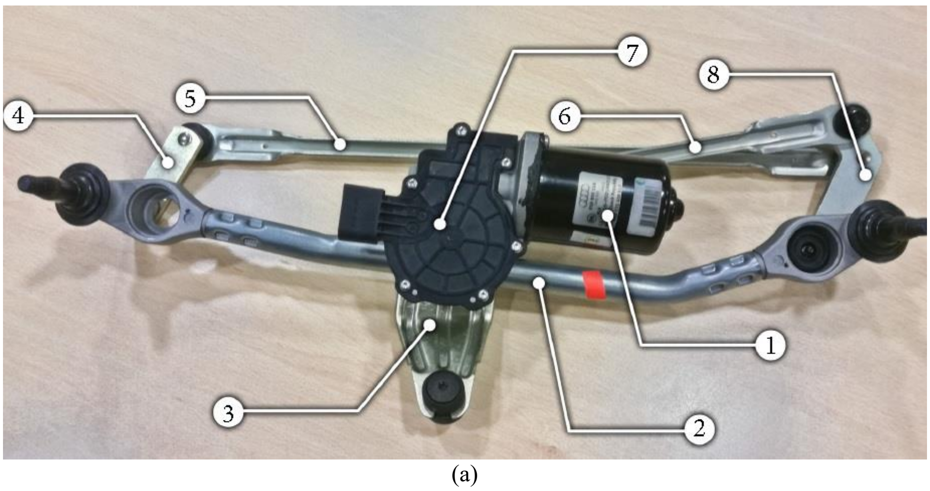


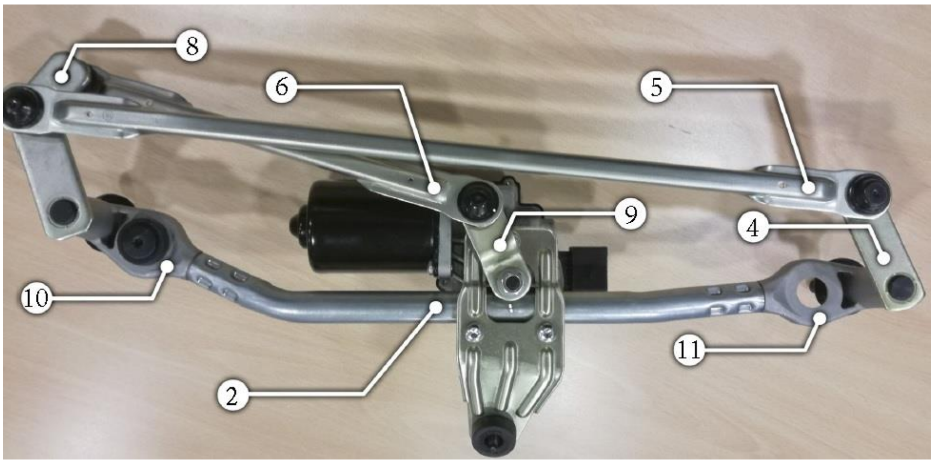
FIGURE 1. Area covered by the wiper blades

The operation areas of each blade and their percentage ratio to the non-treated ones are determined using the autocad software product [9].

This ratio includes area 1 and area 0 if the mechanism is a single blade assembly. If the mechanism is an assembly of two blades, their operation includes area 1, area 2, area 3, which is their overlapping, and area 5, which is the total area of operation of the two blades, regardless of their overlap. The windshield dimensions are assumed to be standard for the present study: 1.5x1.3x0.8m with an area of 1.12m^2 and perimeter of 4.412m. The selected blade sizes are 0.4; 0.5; 0.55; 0.6; 0.65; 0.7m, respectively.



(a)



(b)

FIGURE 2. Windshield wiper's mechanism: a) frond side, b) rear side: 1 - electric motor; 2 - connecting tube; 3 – bracket; 4 - passenger's lever; 5 - conrod; 6 – connecting rod; 7 – gearbox; 8 - driver's lever; 9 – crank; 10, 11 – housings.

RESULTS AND DISCUSSION

The study of the mechanism shown on Figure 3 (a) comprises defining angles φ_4 by the formula (4) and φ_6 by the formula (5) as function of the entry angle φ_2. This mechanism can be treated by a study of the first sub-mechanism shown on Figure 3 (c), comprising defining angle φ_4 by the formula (4) as function of angle φ_2 and defining angle φ_6 by the formula (5) as function of angle φ_4, respectively.

Two triangles can be outlines from the mechanism shown on Figure 3 (c), ΔABD and ΔBCD, respectively. From ΔABD angle φ_{41} has to be defined by the formula (1), and from ΔBCD – angle φ_{42} by the formula (2). Using formulas (1) and (2), we can define $\varphi_4 = \varphi_{41} + \varphi_{42}$ by the formula (4). From the sub-mechanism shown on Fig. 3b angle φ_6 has to be defined by the formula (5).

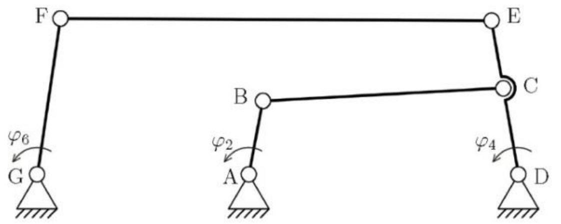
$$\varphi_{41} = arc\,tan\frac{l_1 \sin\varphi_2}{l_{11} - l_2 \cos\varphi_2}. \quad (1)$$

$$\varphi_{42} = arc\,cos\frac{l_4^2 + |BD|^2 - l_3^2}{2l_4|BD|}, \quad (2)$$

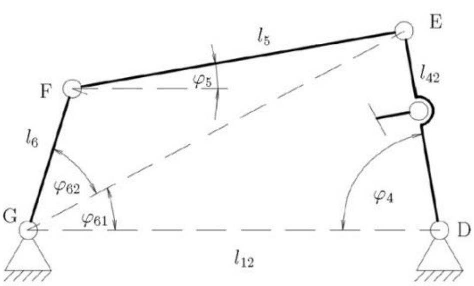
$$where\ |BD| = \sqrt{l_2^2 + l_{11}^2 - 2l_2 l_{11} \cos\varphi_2}\ . \quad (3)$$

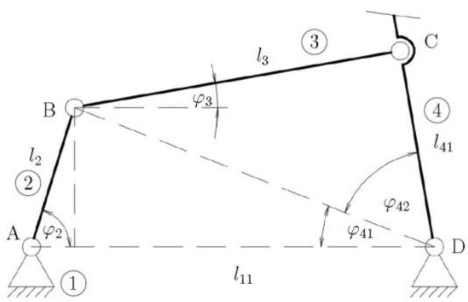
$$\varphi_4 = arc\,tan\frac{l_1 \sin\varphi_2}{l_{11} - l_2 \cos\varphi_2} + arc\,cos\frac{l_4^2 + l_2^2 + l_{11}^2 - 2l_2 l_{11} \cos\varphi_2 - l_3^2}{2l_4\sqrt{l_2^2 + l_{11}^2 - 2l_2 l_{11} \cos\varphi_2}}. \quad (4)$$

$$\varphi_6 = arc\,tan\frac{l_{42} \sin\varphi_4}{l_{12} - l_{42} \cos\varphi_4} + arc\,cos\frac{l_6^2 + l_{12}^2 + l_{42}^2 - 2l_{12} l_{42} \cos\varphi_4 - l_5^2}{2l_6\sqrt{l_{12}^2 + l_{42}^2 - 2l_{12} l_{42} \cos\varphi_4}}. \quad (5)$$



(a)

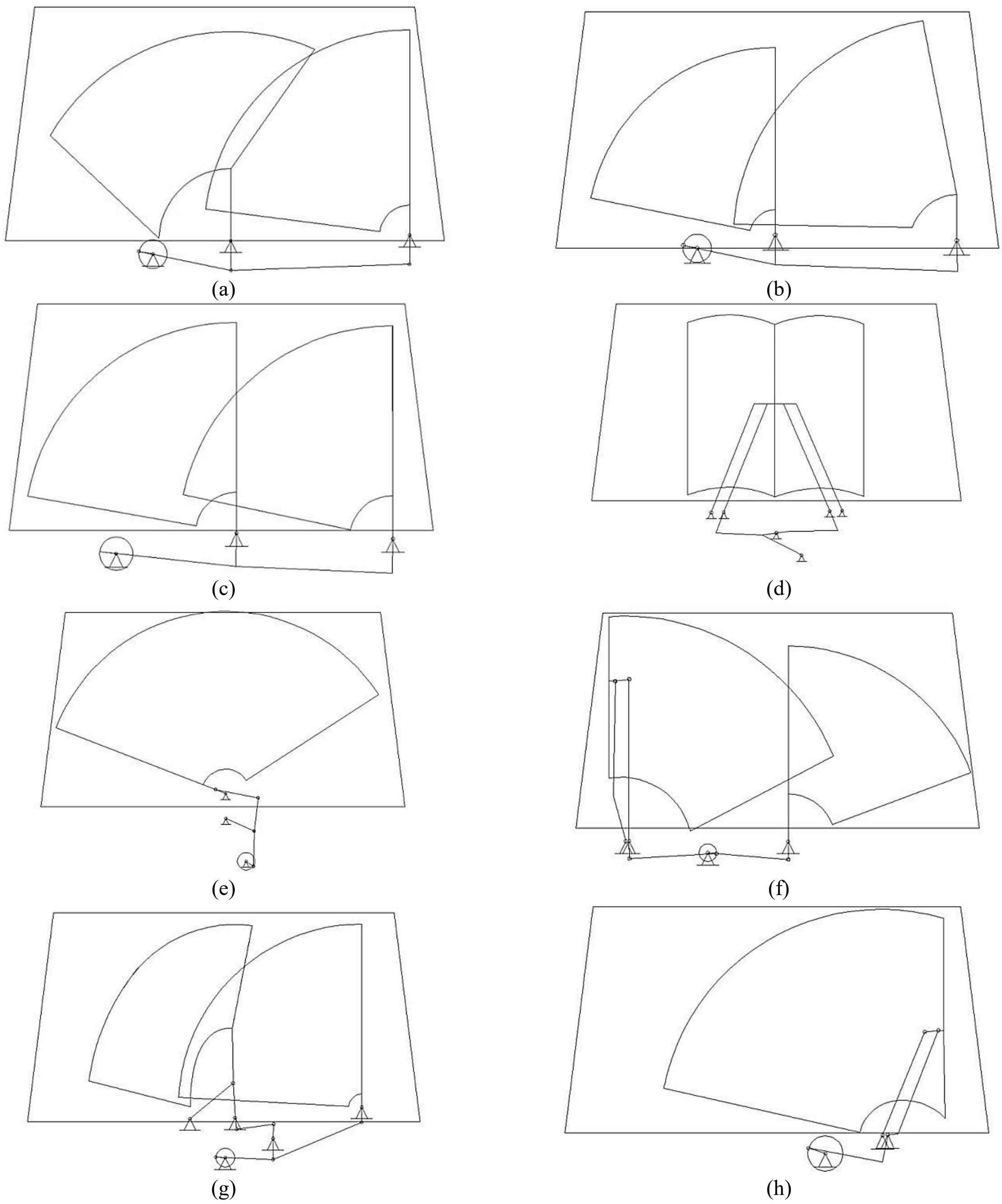


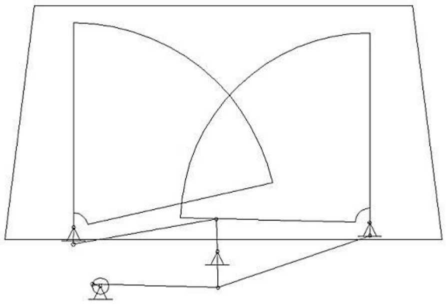


(b) (c)

FIGURE 3. Diagram of the analyzed mechanism: (a) general diagram of a mechanism; (b) diagram of second sub-mechanism; (c) diagram of first sub-mechanism

Of the ten wiper mechanism syntheses shown on Figure. 4 for vehicles, eight mechanisms are two-blade and two mechanisms are single-blade. The common operation angle determined by the formula (4) and formula (5) per blade reaches 88°, found in tandem operation systems, and in single blade systems up to 126°, shown on Figure 4 (e). This angle depends directly on the mechanism assembly. The study of the mechanisms was done for 360° rotation of the gearbox 7 and the crank 9. These angles directly depend on the arm lengths of the passenger and the driver, respectively. The reduction in arm lengths is directly proportional to the increase in the operation angle of the blades. These lengths directly depend on the dimensions of the gearbox cogged wheels.




(i)

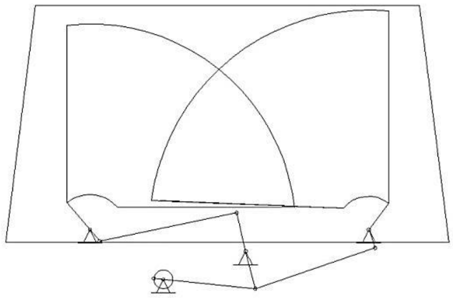

(j)

FIGURE. 4: a, b, c, d, f, g, j – mechanism assemblies with two blades; e, h, i – mechanism assemblies with one blade.

Of the area values shown in Table 1, the mechanism with the largest blade covering area is *c*, shown on Figure 4 (c), and with the smallest – *d*, shown on Figure 4 (d). Basically the covering area of the mechanisms is over 50%. When reviewing the operation of the mechanisms, a combination of more than one operation blades can be assumed, for example the mechanism shown on Figure 4 (h). The assembly of said mechanism allows expansion with an extra blade, which will complicate the mechanism, but will also result in a larger covered area of the glass. In the development of the mechanism shown on Figure 4 (h) extension of the mechanism can be added and addition of a second blade, which will significantly increase the area covered by the mechanism.

TABLE 1. Operation areas of the blades of the individual mechanisms.

	Area 0, m^2	Area 1, m^2	Area 2, m^2	Area 3, m^2	Area 5, m^2	Area covered, %
a	0.475138	0.332526	0.349264	0.026679	0.644862	57.58
b	0.518859	0.272688	0.363203	0.03189	0.601141	53.67
c	0.417428	0.375214	0.372653	0.042644	0.702572	62.73
d	0.62519	0.247405	0.247405	-	0.49481	41.5
e	0.512825	0.607175	-	-	0.607175	54.21
f	0.41816	0.433008	0.300943	0.032147	0.701804	62.66
g	0.526157	0.257144	0.369521	0.032823	0.593843	53.02
h	0.542621	0.577379	-	-	0.577379	51.55
i	0.531513	0.329339	0.324368	0.065181	0.588487	52.54
j	0.480792	0.369999	0.411664	0.142455	0.639208	57.08
MIN					0.49481	41.5
MAX					0.702572	62.73

CONCLUSIONS

The arrangement of a tandem wiper mechanism has been shown and explained. The formulas for the operation angles of the driving levers for the passenger and driver, respectively, have been derived. The percentage ratios of the covered areas have been calculated depending on the dimensions of the blades and their operation angles. Tandem and single blade operation systems and their respective percentages of covered and non-covered areas have been shown.

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